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(56) Documents Cited
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WO 87/05376 A1 WO 87/03840 A1 JP 620027134 A
JP 590155010 A JP 580167156 A JP 580087018 A

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(54) Abstract Title
Multilayer liner pipe comprising a cross-linked polyolefin

(57) The invention relates to a method of lining a host pipe 10 comprising inserting into the host pipe a liner pipe 4,6 having a multilayer structure, the multilayer structure comprising at least one layer 6 formed from a cross-linked polyolefin. Preferably, at least one of the inner and outer surface layers of the liner pipe comprises the cross-linked polyolefin. The liner pipe is preferably inserted into the host pipe in a deformed configuration before being radially expanded against the wall of the host pipe.

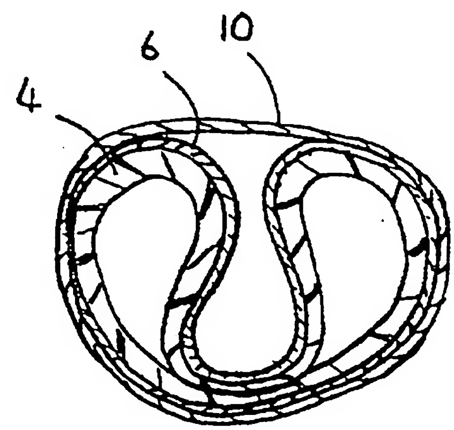

FIG. 4

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

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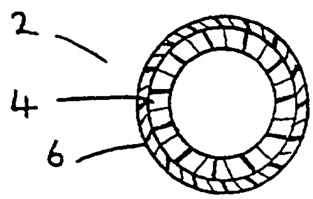

FIG. 1

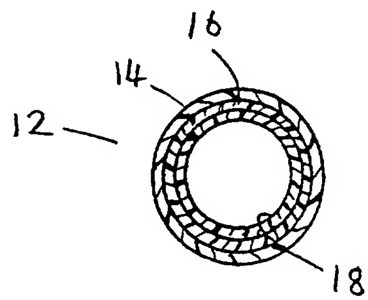

FIG. 2

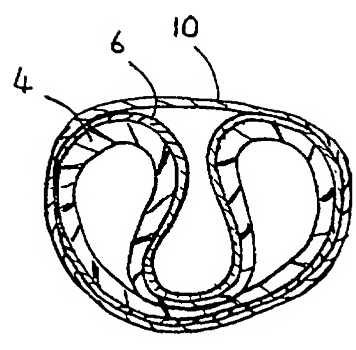

FIG. 4

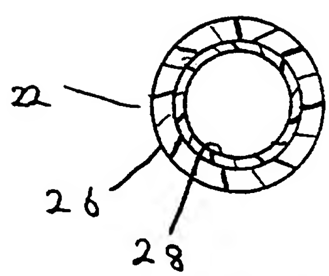

FIG. 3

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IMPROVEMENTS IN AND RELATING TO PIPES

This invention relates to pipes, and more particularly to liner pipes, as well as methods of lining a pipe line and to pipelines thus lined.

In recent years, it has become established practice to extend the useful life of damaged, faulty and/or leaking pipes, such as water pipes or gas pipes, where the pipe is reasonably structurally sound, by providing the pipe with an impervious lining.

One of the problems encountered has been to ensure that lining of the pipe does not lead to a significant reduction in the carrying capacity of the pipe.

In order to allow a liner pipe to be hauled through a host pipe during a lining operation, there will normally need to be a clearance between the liner pipe and host pipe to prevent friction between the liner and the host pipe wall or snagging of the liner pipe against the host pipe wall impeding its progress through the host pipe. However, a problem is that if the liner pipe has a significantly smaller radius than the host pipe, this will lead to a considerable reduction in the carrying capacity of the pipeline. Therefore, in order to avoid this problem, many techniques have been developed in which the liner pipe is first collapsed or deformed to reduce its effective diameter during installation in the host pipe, and is then subsequently expanded to its original size or beyond in order to give a relatively close fit against the host pipe wall. In this way, the reduction in volume of the host pipe is relatively minimal.

Examples of known methods for lining pipelines are the methods disclosed in EP-A-0098547, EP-A-000576, GB-A-2003576, WO-A-95/32381, US-A-5205886, WO-A-95/20125, GB-A-2251472, GB-A-2251471, WO-A-87/03840, EP 301 697, EP 0 514 142 and GB-B-2 084 686..

Liner pipes are commonly formed from polyethylene. Whereas polyethylene is generally a most suitable and convenient material, there are circumstances in which its

properties are not ideal. For example, in host pipes having tight bends, or where there are protrusions into the pipe bore such that the liner pipe is subject to increased abrasion, ordinary polyethylene can be insufficiently abrasion resistant to withstand such severe local wear. In addition, where there are protrusions into the host pipe bore, such as redundant branch pipe off takes, there may be severe local strains on the liner where it forms round the protrusion. Such tensile strains can lead to premature stress cracking in service. A further drawback with ordinary polyethylene is that its resistance to hydrocarbons is less than is ideally desirable.

Therefore, an object of the present invention is to provide a liner pipe having enhanced properties, for example enhanced abrasion resistance, stress crack resistance and hydrocarbon resistance that enable it to overcome the problems described above. It has now been recognised by the inventors that such enhanced properties can be imparted to the liner by forming the outer and/or inner surface of the pipe from a crosslinked polyolefin material.

Accordingly, in a first aspect, the invention provides a method of lining a host pipe comprising inserting into the host pipe a liner pipe having a multilayer structure, the multilayer structure comprising at least one layer formed from a cross-linked polyolefin.

In a second aspect, the invention provides a liner pipe *per se* of the aforesaid type.

In a further aspect, the invention provides a liner pipe of the aforementioned type that has been reversibly deformed (e.g. by folding) from an original diameter to a reduced effective diameter.

In a still further aspect, the invention provides a host pipe lined with a liner pipe as hereinbefore defined.

Typically a surface layer of the liner is formed from the crosslinked polyolefin. For example, a radially outer surface layer of the liner can be formed from the crosslinked polyolefin and/or a radially inner surface of the liner can be formed from a crosslinked polyolefin.

In one embodiment, only the radially outer layer of the liner is formed from the crosslinked polyolefin. In another embodiment, only the radially inner layer of the liner is formed from the crosslinked polyolefin.

In a still further embodiment, both the radially inner and radially outer layers of the liner are formed from a crosslinked polyolefin.

Where both the radially inner and radially outer layers are formed from a crosslinked polyolefin, the same crosslinked polyolefin can be used for both layers, or different crosslinked polyolefins may be used. In a preferred embodiment, the layers are both formed from the same crosslinked polyolefin.

In general, the or each crosslinked polyolefin layer constitutes no more than 25% of the total thickness of the wall of the liner.

The crosslinked polyolefin is typically a crosslinked polyethylene, although other crosslinked polyolefins could be used.

The degree of crosslinking can be determined by measurement of the gel content, for example in accordance with the method of ISO/DP10147. The term "gel content" as used herein means the residual polyolefin remaining following exhaustive extraction of the non-crosslinked polyolefin material with a hydrocarbon solvent such as toluene or xylene. The gel content can conveniently be determined using a Soxhlet extraction apparatus or by boiling in a suitable vessel. The extraction of the uncrosslinked polyolefin is carried out over a period of at least five hours, and up to twenty four hours. An inert atmosphere of nitrogen or other means to prevent oxidated degradation may be provided. The dried residue, expressed as a percentage of the initial sample mass gives the gel content (percentage). In general, the gel content of the crosslinked polyethylene will fall within the range 65%-90%, the precise level of crosslinking depending upon the crosslinking technique used.

An advantage of the liner pipes of the present invention is that they provide the advantages associated with the use of crosslinked polyolefins, but avoid the disadvantages associated with crosslinked polyolefin, for example the increased difficulty in joining the

materials by fusion jointing.

For example, liners of the present type, wherein the outer surface of the liner is constituted by a layer of crosslinked polyolefin, have particular advantages in the lining of pipes where there are severe bends to be negotiated or where there are disused and/or intruding off-takes that are costly or impossible to remove. In the case of severe bends, unusually high levels of abrasive wear can occur, and in the case of intruding off-takes and other similar redundant intrusions, severe local wear may occur on a liner during its insertion. In addition, after insertion and reversion of the liner by whatever means to form a close fit, local tensile strains on the bore of the liner that has formed around an intruding object can lead to premature stress cracking in service. The advantage of using a layer of crosslinked polyolefin on the outer surface of the liner pipe is that the crosslinked polyolefin has much greater resistance to abrasion and stress crack formation than non-crosslinked polyethylene.

A further advantage of the use of crosslinked polyolefins as the outer layer in accordance with the present invention is that the crosslinked polyolefin outer layer provides enhanced resistance to hydrocarbons and oils, for example found in old gas mains.

In circumstances where internal oil resistance or stress crack resistance is required, the crosslinked polyolefin provides a much greater resistance than non-crosslinked material.

As described hereinabove, the or each crosslinked polyolefin layer will typically each form no more than 25% of the overall wall thickness of the liner pipe, and more usually will be less than 25%, e.g. less than 20%.

The absolute thickness of the crosslinked polyolefin layer will depend to some extent on the overall thickness of the liner pipe wall in that an increased overall wall thickness will enable the crosslinked polyolefin layer to be made thicker, and *vice versa*. The layer construction of the liners of the present invention is particularly (although by no means exclusively) suitable for relatively thin walled liner pipes, for example liner pipes having an SDR value of 20 or greater, for example 25 or greater, e.g. 26 or greater.

For relatively thin walled pipes of the aforesaid type, for example in the case of liner pipes having a total wall thickness of 10 mm, the or each crosslinked polyolefin layer will typically have a thickness of less than 2.5 mm, more usually less than 2 mm, and typically less than 1.5 mm.

The other layers in the multi-layer liner pipe are typically formed from uncrosslinked polyolefin, or another polyolefin based material, such as an olefin copolymer, or a graft copolymer containing an olefin such as polyethylene. Tie layers (eg of less than 1 mm thickness) may be positioned between the crosslinked polyolefin and other polyolefin based materials as required. Such tie layers, if present, can be formed from adhesive polymers such as polyolefins having acyl groups (e.g. maleic anhydride) grafted thereon or copolymers of polyolefins containing acyl groups.

In a preferred embodiment, the liner pipe comprises a main structural layer of a non-crosslinked polyolefin, such as non-crosslinked polyethylene, together with a radially outer and/or radially inner surface layer of crosslinked polyolefin (eg crosslinked polyethylene).

The liner pipes of the invention are generally formed by extrusion in standard fashion. In order to provide a multi-layer structure, a co-extrusion process can be used. For example, co-extrusion can be effected using a co-extrusion tool fed by a separate extruder for each material to be incorporated into the extruded pipe section. Thus, for example, a three layer pipe having an inner core layer of polyethylene with surface layers of crosslinked polyethylene may be supplied by two extruders, one for polyethylene and one for the crosslinked polyethylene precursor. The co-extrusion tool is typically designed so that flow channels provide for the supply and formation of a circular pipe form with discrete layers of materials in the prescribed form. Co-extrusion will generally result in the layers fusing together so that the pipe wall behaves as a unitary body having the combined properties of the component layers as required.

As an alternative to co-extrusion, a pipe can be extruded initially with one or more layers, and then additional layers can be added in one or more separate extrusions steps using an annular die. By adjusting the extrusion conditions and the materials as appropriate, the additional layers can either be fused to the underlying layers or can be

made peelable. An advantage of making the outer layer peelable is that it can easily be removed, for example to permit fusion coupling of the liner to another polyolefin body such as another liner.

As the level of crosslinking of the polyolefin increases, so the polymer becomes increasingly less thermoplastic in nature and hence more difficult to extrude without using very high pressure ram extruders. It is therefore preferred that crosslinking to form the crosslinked polyolefin layer is effected after the extrusion of the liner. Thus, the "crosslinked" polyolefin layers are preferably extruded as a crosslinkable precursor. By "crosslinkable precursor" in the present context is meant a polymer such as polyethylene which has been specially formulated or treated to render it susceptible to crosslinking when subjected to suitable activating conditions. After extrusion, the crosslinkable precursor is activated by subjecting it to the conditions required to bring about crosslinking.

In a further aspect therefore, the invention provides a liner pipe having a multilayer structure, the multilayer structure comprising at least one layer formed from a crosslinkable precursor to a crosslinked polyolefin. The crosslinkable precursor may take the form of a polymer composition containing an activatable cross-linking group.

In one embodiment, the activatable crosslinking group is a group (such as a silane group) which is activatable under conditions of humidity and optionally heat to bring about crosslinking of the polyolefin in the crosslinked precursor layer.

Silane crosslinking involves the chemical modification of polyethylene by grafting functional groups onto the polyethylene during extrusion, which functional groups can subsequently be caused to crosslink by a further separate chemical linking reaction. After extrusion, the crosslinking is typically brought about by heat and moisture in the presence of a catalyst. The speed of the crosslinking reactions is largely dependant upon the temperature, crosslinking taking place very slowly at ambient temperatures and humidity, but being capable of being accelerated significantly by employing hot water or steam such that even relatively thick pipe walls can be fully crosslinked in a few hours at temperatures up to 120°C. Silane-containing pipes after manufacture are still thermoplastic in nature and can be melted, reshaped, even recycled, for a period of time before significant

crosslinking under ambient conditions takes place. Crosslinking in this case takes place while the polymer is in its solid phase, all crosslinking occurring in the amorphous regions of the material such that the crystallinity is not significantly disturbed. Silane crosslinked polyethylene therefore maintains a similar density, strength and stiffness to the original polyethylene material from which it is made. After being fully crosslinked, the pipes are more difficult to join by fusion welding techniques and can no longer be recycled.

In another embodiment, the crosslinkable precursor is a polymer composition specially formulated to render it sensitive to electron beam crosslinking. After extrusion, the pipe is passed through an electron beam unit for crosslinking by means of a conveying unit. The electrons penetrate into the plastic and interact with the material forming free radicals which combine to form crosslinks. Crosslinking takes place at ambient temperatures so that the original density, strength and stiffness of the polyethylene are maintained. Once exposed to the electron beam, the pipes become fully crosslinked and thereafter can no longer be joined by fusion welding techniques.

Once the liner pipe has been formed by extrusion and crosslinked, it may then be subjected to a deforming step in order to bring about a reduction in its effective diameter, the term "effective diameter" meaning the maximum cross sectional dimension of the liner in its deformed state. For example, it may be folded, e.g. to form a U-shape or C-shape profile in cross section, to present a smaller cross sectional area. Alternatively, the liner pipe can be subjected to a series of radial deformations by means of rollers to give a liner pipe having a substantially circular cross section but reduced radius relative to its original undeformed state. Examples of methods of deforming pipes by the aforementioned methods are described in, for example, GB-B-2 084 686, EP-A-0 301 698 and EP-0 514 142.

The liner pipe can be deformed following extrusion and then coiled for storage and transportation. Where necessary, restraining straps may be fastened about the deformed liner in order to prevent it from resiling towards its original shape, particularly in the case where the liner is folded. Alternatively, at certain pipe diameters, the liner pipe can be coiled and stored in an undeformed state and then subjected to a deforming technique immediately prior to installation in a host pipe.

Once installed, the liner can be expanded to its original size, or even stretched to a larger diameter, by the application of pressure and optionally heat. For example, the liner can be expanded by means of compressed air, steam or hot or cold water. In this way, the liner can form a close fit against the wall of the host pipe thereby minimising any reduction of the carrying capacity of the host pipe.

The presence of the crosslinked polyolefin layer or layers, in addition to providing the enhanced properties described above, also assists in the restoring of the liner to its original shape as a consequence of the greater elasticity of the crosslinked polyolefin compared to its uncrosslinked form, and the fact that the crosslinked polyolefin exhibits some "memory" for the original circular form as crosslinked..

The invention will now be illustrated by way of example, but not limited, by reference to the particular embodiments shown in the accompanying schematic drawings, of which:

Figure 1 is a sectional elevation though a two layer pipe according to one embodiment of the invention;

Figure 2 is a sectional elevation though a three layer pipe according to a second embodiment of the invention;

Figure 3 is a sectional elevation though a two layer pipe according to a third embodiment of the invention; and

Figure 4 is a sectional elevation though the two layer pipe of Figure 1 illustrating the pipe in a deformed and folded C-shape configuration.

Referring now to the drawings, Figure 1 illustrates a two layer pipe 2 having a thicker inner or core layer 4 of a non-crosslinked polyethylene and an outer layer 6 formed from a crosslinked polyethylene. The crosslinked outer layer has a thickness of 1mm which approximates to 25% of the total wall thickness of the pipe.

The pipe shown in Figure 1 can be prepared by means of a coextrusion process in which a suitably configured co-extrusion tool is fed by separate extruders providing an inner core layer of the non-crosslinked polyethylene such as "EITEX TUB171" from Solvay Polyolefins Europe, and an outer layer of a crosslinkable silane grafted polyethylene composition such as "ELTEX TUX100" from the same supplier. Following

extrusion, the pipe is subjected to heat and humidity, for example hot water at 80°C for several hours (the precise time depending on the thickness of the crosslinked polyolefin layer) in order to bring about crosslinking to give a degree of crosslinking corresponding to a gel content of at least 60% and preferably 70%.

After the crosslinking step is complete the pipe is subjected to a cold deforming process using an array of deforming rollers or other deforming means of the type shown in GB-B-2 084 686, EP-A-0 301 698 and EP-0 514 142 to give a pipe having a U-shape in cross section as shown in Figure 4. Any tendency of the pipe to resile away from the C-shape is arrested by means of a supporting strap(s) or band(s) 10 which may be helically wound about the pipe or be present as a series of discrete bands or straps positioned at spaced intervals along the length of the pipe.

The pipe shown in Figures 1 and 4 has an outer layer of a crosslinked polyethylene and an inner layer of a non-crosslinked polyethylene. The outer crosslinked layer provides protection when the pipe is hauled through an existing but damaged host main, particularly at locations within the host pipe where there is increased abrasion between the pipe and the host pipe wall, for example at tight bends, or at protruding off takes to branch pipes, or in areas where the host pipe wall has fractured and presents sharp edges.

Once the liner pipe 2 has been hauled into place within the host main, it can then be radially expanded from the C-shape to its original circular cross sectional shape to provide a close fit against the wall of the host pipe. The fact that the outer layer is formed from crosslinked polyethylene means that there is enhanced natural recovery of the liner from its C-shape towards the circular shape, as a consequence of the more pronounced elastic behaviour of crosslinked polyolefins.

A second embodiment of the invention is shown in Figure 2. The pipe 12 shown in Figure 2 has a three layer structure comprising an outer surface layer 14 formed from a crosslinked polyethylene, an intermediate or "core" layer 16 formed from non-crosslinked polyolefin, and an inner layer 18 of crosslinked polyethylene. Each of the inner 18 and outer 14 crosslinked polyethylene layers is of approximately 1 mm thickness and hence each contributes approximately 25% to the total wall thickness (4 mm) of the liner pipe. The pipe may be formed by a co-extrusion method of the type described above

with regard to Figure 1. An advantage of the liner pipe shown in Figure 2 is that by virtue of having both inner and outer surfaces formed from crosslinked material, the pipe has enhanced abrasion resistance on the outside and enhanced resistance to hydrocarbon materials such as oil on the inside.

In circumstances where abrasion resistance is considered less important, but enhanced resistance to hydrocarbons is needed, the liner may be provided with a surface layer of crosslinked polyethylene on only the radially inner surface. An example of such a liner pipe is shown in Figure 3. Thus, the liner pipe of Figure 3 comprises a main structural layer 26 formed of uncrosslinked polyolefin and an inner surface layer 28 formed from a crosslinked polyethylene.

The foregoing examples illustrate merely some of the possible configurations of layers that may be used in the liner pipes of the invention, but it will readily be apparent that numerous modifications and alterations could be made to the illustrated pipes without departing from the principles underlying the invention. For example, the illustrated embodiments show pipes having only two or three layers, but additional layers could included such as tie layers of adhesive polymers to assist in bonding the layers together, or intermediate barrier layers to enhance the resistance of the liner to permeation to gases. All such modifications and alterations are intended to be embraced by this application.

CLAIMS

1. A method of lining a host pipe comprising inserting into the host pipe a liner pipe having a multilayer structure, the multilayer structure comprising at least one layer formed from a cross-linked polyolefin.

2. A method according to claim 1 in which a surface layer of the liner is formed from the cross-linked polyolefin.

3. A method according to claim 2 wherein a radially outer surface layer of the liner is formed from the cross-linked polyolefin.

4. A method according to claim 2 or claim 3 wherein a radially inner surface of the liner is formed from a cross-linked polyolefin.

5. A method according to claim 4 wherein both the radially inner and radially outer layers of the liner are formed from a cross-linked polyolefin.

6. A method according to claim 5 wherein the radially inner and radially outer layers are formed from the same polyolefin.

7. A method according to any one of the preceding claims wherein the or each polyolefin layer constitutes no more than 25% of the total thickness of the wall of the liner.

8. A method according to any one of the preceding claims wherein the liner is introduced into the host pipe in a deformed radially reduced configuration and is subsequently subjected to radial expansion towards the wall of the host pipe.

9. A method according to claim 8 wherein the liner is deformed and radially reduced by virtue of being folded.

10. A method according to claim 9 wherein the liner is folded to present a U-shaped cross section.

11. A liner pipe as defined in any one of the preceding claims.

12. A liner pipe according to claim 11 in a deformed radially reduced state.

13. A liner pipe according to claim 12 which is radially reduced by virtue of being folded.

14. A liner pipe according to claim 13 which is provided with removable or breakable means (such as straps) for restraining the folded liner against unfolding.

15. A liner pipe as defined in any one of claims 11 to 14 having a total wall thickness of less than 10 mm.

16. A liner pipe according to claim 15 wherein the total wall thickness is less than 5 mm.

17. A liner pipe according to any one of claims 11 to 16 having an SDR of greater than 20, for example greater than 25.

18. A host pipe having disposed therein a liner pipe as defined in any one of claims 11 to 17.

19. A liner pipe having a multilayer structure, the multilayer structure comprising at least one layer formed from a crosslinkable precursor to a crosslinked polyolefin..

20. A liner pipe according to claim 19 wherein the crosslinkable precursor contains an activatable cross-linking group.

21. A liner pipe according to claim 20 wherein the activatable crosslinking group is a group (such as a silane group) which is activatable under conditions of humidity and optionally heat to bring about crosslinking of the polyolefin in the crosslinked precursor layer.

22. A liner pipe substantially as described herein with reference to the accompanying drawings.

23. A method of lining a host pipe which comprises inserting into the host pipe a liner pipe substantially as described herein with reference to the accompanying drawings.

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Application No: GB 9930507.0
Claims searched: 1-23

Examiner: Dr Steve Chadwell
Date of search: 11 May 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): F2P (PM9, PR, PTBL)

Int Cl (Ed.7): B29C 63/00, 63/34, 63/36, 63/42; B32B 1/08; F16L 55/165, 58/10

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	GB 2003576 A	(TRIO...) See figure 2	10,14
X	EP 0738581 A1	(MOSKOVSKOE...) See whole document	1-7,11, 18-21
X,Y	WO 97/10936 A2	(UPONOR) See page 14 line 10 to page 15 line 24	X: 1-6,8, 9,11-13, 18-20 Y: 10,14
X	WO 87/05376 A1	(UPONOR) See page 6 lines 1 to 28	1,2,4,11, 18,19
Y	WO 87/03840 A1	(SKOTT) See figures 3, 4 and 6	10,14
X,Y	JP 620027134 A	(FuRUKAWA...) See figures, PAJ English language abstract, and also WPI Abstract Accession No. 1987-075324 [11]	X: 1-6,8, 9,11-13, 18-21 Y: 10,14
X	JP 590155010 A	(SUMITOMO...) See figures, PAJ English language abstract, and also WPI Abstract Accession No. 1984-254315 [41]	1,2,4,11, 18,19
X	JP 580167156 A	(SUMITOMO...) See figures, and also WPI Abstract Accession No. 1983-811891 [45]	1,2,4,11, 18,19

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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12
INVESTOR IN PEOPLE

Application No: GB 9930507.0
Claims searched: 1-23

Examiner: Dr Steve Chadwell
Date of search: 11 May 2000

Category	Identity of document and relevant passage		Relevant to claims
X	JP 580087018 A	(SUMITOMO...) See figures, PAJ English language abstract, and also WPI Abstract Accession No. 1983-62859K [26]	1,2,4,11, 18,19

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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